Pushing the Envelope on Rate Design

A new crop of rate cases provides a unique window of opportunity to rationalize rate designs so that they more accurately reflect the underlying economics of electricity supply, so that prices are more easily understood by customers, and so that they provide more accurate and cost-effective incentives for energy efficiency and demand response.

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I. Introduction

A new wave of rate cases is sweeping the country, deriving its energy primarily from the expiration of rate freezes that were instituted in the mid- to late-1990s and secondarily from the need to modernize aging transmission and distribution infrastructures. The Energy Policy Act of 2005 may spark additional interest, since Section 1252 calls for each electric utility to provide customers a time-based rate schedule on their request within 18 months of enactment of the Act. It also calls upon regulatory commissions to conduct an evaluation of time-based rates as a way of fostering demand response and to launch an investigation into whether investment in advanced metering to enable time-varying pricing and demand response for all customers is cost-effective.

The last big wave of rate cases was in the mid- to late-1970s, and it was triggered by rising oil and gas prices and general inflationary pressures. The term ''rate shock'' was coined during that wave. The number of rate cases dropped from 40 to 10 between

1992 and 1999, as utilities and commissions shifted their focus to restructuring power markets.[1]

Reflecting new business conditions, state regulatory commissions dealt with as many as 26 new rate cases in 2004. Michael McGrath and Ronald Seeholzer prognosticate that the electric industry will face ''as much as $40 billion in rate reviews during a time of tremendous regulatory uncertainty and its related anxiety in the financial community. Moreover, the outcome of many of these reviews will be increased rates for consumers—always an unpopular choice and a major political challenge for state commissioners.''[2]

In a nutshell, the goal of utility ratemaking is to set future rates that allow a utility to collect enough revenue in the period when the rates are in effect to cover the utility's costs and an adequate, but not excessive, return on investment. The process of setting tariffs consists of two major steps. The first step is called ratemaking and involves a determination of revenue requirements. The second step is called rate design and involves the allocation of revenue requirements into functions (generation, transmission, and distribution), class of service (residential, commercial, government, agricultural, and industrial), voltage level (primary, secondary, and tertiary), category (demand, energy, and customer) and time of use (seasonal, time-of-day).

Much time in such cases will be spent on ratemaking, which will involve defining a utility's rate base and establishing an authorized rate of return, in addition to specifying its operating costs. This process will yield rate levels. But it would be equally important for commissions and utilities to set aside quality time in these rate proceedings to revisit the premises of existing rate designs, many of which have had unintended consequences in the past couple of decades. This is as good a time as any to push the envelope on rate design.

A major problem with existing rate regulation is that prices cease to convey information on resource scarcity.

Rates have become extremely complex in the last several decades as they have been modified to reflect multiple and sometimes conflicting objectives of encouraging energy efficiency and reducing peak loads, while addressing equity and environmental concerns. Thus, the typical bill is encumbered with a plethora of features such as lifeline/baseline rates, inverted block rates, public goods charges to promote energy efficiency and renewables, revenue stabilization charges, and rate unbundling information. The opacity of these features to most customers has not deterred either commissions or utilities from putting them on customer's bills. It is no surprise that customers cannot comprehend and have trouble responding to the price signals embedded in these rates.

A major problem with existing rate regulation is that prices, whose primary purpose is to accurately reflect resource scarcity to customers so they can make efficient consumption decisions, cease to convey such information. Second-best, third-best, and even fourth-best solutions become inevitable in such an environment.

In part because of such complexity and in part because, even with such complexity, tariffs too often do not accurately reflect the underlying economics of electricity supply, regulators and utilities have relied on other mechanisms, such as demand-side management (DSM) incentives, to encourage energy efficiency and demand response. However, DSM incentives in the form of cash rebates and low-interest loans can be very blunt instruments that often pay some customers too much for the benefits achieved and pay others less than is economically justified. They create another set of cross-subsidies between customers, causing resentment and friction, and in the end lead to inefficient consumption decisions. In addition, they create dissonance and uncertainty in the market for

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efficient appliances, building designs, and processes.

II. California's Energy 20/20 Rebate Program

A typical example of an ad hoc ''rate design'' that has caused much inefficiency and wealth transfer is California's Energy 20/20 cash rebate program. This was created through an executive order by then-Gov. Gray Davis in California during the height of the energy crisis in 2000-01 when he realized he could not raise energy prices in order to balance demand with supply.[3] Under the 20/20 program, customers who lowered usage by 20 percent during a summer month in 2001 were given a bonus credit of 20 percent in their bill. This was over and above the 20 percent reduction on the bill that occurred because of conservation (lower usage). The program was widely credited for helping achieve 2,600 MW of peak demand savings and 3,053 GWh of energy savings during the critical summer peak consumption months from June to September 2001. The program dominated the state's energy saving during 2001, accounting for about two-thirds of the total. About 30 percent of customers benefited from the program. The program cost $415 million, which ultimately will be recovered from all customers.[4]

Subsequent analysis revealed that the program had several flaws, including a high incidence of free riders, a low cost-benefit ratio, and a failure to link the time period during which customers reduced usage with system needs.[5] Even then, it was extended the following year by the California Public Utilities Commission and reinstated in the summer of 2005. One utility estimates that the program reduced peak demand at a cost of $276/kW-yr, compared with the marginal cost of supplying demand of electricity of $55/kW-yr.[6]

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The logic of such conservation rebate programs is entirely political. They are very popular with customers who receive the benefits and those who don't get the benefits don't seem to complain. It is one more instance in regulatory decision-making where the value of ''doing something good'' trumps the value of doing something that is economically efficient.[7]

III. Brazil's Two-Part Rate Design

Contrary to conventional wisdom, new ideas can flow north in the Americas, not just south. An alternative way of lowering consumption during times of crises that would be much more economically efficient than the examples discussed above is a program that was pioneered in Brazil during its power crisis in 2001.[8] Brazil, which generates 80 percents of its energy from hydroelectric resources, faced a generation shortfall of 20 percent caused by drought. Decision-making in Brazil was not hampered by the political considerations that have prevented economically efficient pricing by commissions in the U.S. Brazil developed a rate program that gave customers a two-tier rate signal. Customers were charged the standard rate for consumption up to a pre-set limit and charged a higher price based on marginal costs for usage above the limit. Brazil established mandatory targets for saving energy that varied by sector. Low household users that consumed less than 100 kWh had no savings target. All other households had a target of 20 percent (i.e., a pre-set limit of 80 percent). Industries and government buildings had targets that varied between 15 and 25 percent, while public lighting had a target of 35 percent. To lower demand, it instituted penalties and incentives. For example, customers who did not meet the targets were subject to interruption of supply. In addition, consumption in excess of the quota was subject to price increases of 50 percent for customers in the 210–500 kWh

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bracket and of 200 percent for customers consuming more than 500 kWh per month. Small customers were offered a bonus for each kWh saved in excess of their quota. To assist poor customers, the government purchased 5.6 million compact fluorescent lamps and gave them as a grant to them. This approach was adopted subsequently by Argentina to deal with a power shortage in the country. The shortage was less severe than that encountered in Brazil and the quotas were set to achieve a savings of 7 percent.

IV. Criteria for Evaluating Rate Designs

The new crop of rate cases in the U.S. provides a unique window of opportunity to rationalize rate designs so that they more accurately reflect the underlying economics of electricity supply, so that prices are more easily understood by customers, and so that they provide more accurate and cost-effective incentives for energy efficiency and demand response.

It will not be easy to implement significant improvements but it can be done if the political will is there. New thinking will be needed to assess the weaknesses of existing rates and to develop new ones. To help guide decision-making, the remainder of this article discusses some of the key criteria that should be used to evaluate the next generation of rate designs.

Table 1: Bonbright's Criteria for Ratemaking

1. Does the rate provide adequate revenue recovery to the utility?
2. Does the rate promote fairness in cost allocation (equity between customer classes)?
3. Does the rate promote efficient resource use?
4. Is the rate practical to implement (understanding, acceptance)?
5. Is the rate easy to interpret (non-controversial)?
6. Does the rate provide revenue stability for the utility?
7. Does the rate provide bill stability for customers?
8. Does the rate avoid undue discrimination among customers?

Interestingly, as we look for guidance concerning how best to improve pricing in the future, we can actually look back several decades to Prof. James Bonbright's canon, *Principles of Public Utility Rates*.[9] The eight criteria listed in **Table 1** are as relevant today as they were then and they apply equally to standard or default rate designs as they do to optional ones.

Clearly, the problem is not one of knowing what matters in rate-making. It is one of figuring out how to apply these criteria in practice.

A. Economic efficiency

Bonbright's third criterion, ''efficient resource use,'' is another way of saying economic efficiency. The desire to achieve economic efficiency has been one of the key drivers underlying the increasing complexity of electricity pricing in the last two to three decades. Increasing block rates are designed to reflect the fact that the marginal cost of electricity supply now exceeds the average cost, and time-varying prices reflect the time-varying nature of electricity supply costs.

A tariff that incorporates both an increasing block structure and time-varying pricing can provide adequate price incentives for encouraging energy efficiency *and* demand response. On the other hand, challenges in implementing such economically efficient pricing have been a key driver in the use of incentives to promote economic efficiency and demand response. Incentives for energy efficiency are designed to account for the market failure in setting correct electricity prices that incorporate social marginal costs. Incentives for demand-response options such as direct load control reflect the historical perception that load control technology is cheaper than time-of-use metering and the perception that behavioral response to time-varying pricing is more unreliable than push-button technology options.

Designing economically efficient rates, even ones that incorporate the inherent uncertainty in supply conditions, is not hard. What is difficult is designing economically efficient rates that customers understand well, that overcome the political challenge of transitioning from longstanding cross-subsidies to more equitable and efficient cost allocation, and that can be implemented cost-effectively. The interplay and tradeoffs between economic efficiency and the other Bonbright criteria needs to be re-examined and re-thought in future regulatory deliberations.

B. Customer understanding

California's residential electricity tariffs, with their increasing block structure, subsidies and surcharges and unbundled cost structure, are probably the most convoluted of all tariffs in the country (if not the world), and that is before incorporating time-varying surcharges and credits and dynamic price variation as was done in California's landmark pricing experiment, the Statewide Pricing Pilot (SPP).[10] The SPP examined the load-shape impact of several time-varying rate options, including traditional TOU rates and several types of critical peak pricing (CPP). The SPP was based on modern principles of experimental design and featured before/after and side/side measurements being carried out through treatment and control groups. It involved some 2,500 customers from July 2003 to December 2004.

Indeed, research done under the SPP indicated that many customers did not understand even the basic characteristics of their standard rates let alone the nuances of how average and marginal prices move across rate tiers and time periods. On the other hand, the SPP showed that many customers did understand that prices were much higher during peak periods on critical days. The SPP also showed that time-varying prices can produce significant peak demand reductions even in a world of significantly increasing block tariffs and rate complexity. In other words, the SPP showed that even complex rates can produce demand response. What the SPP did not show, however, is whether significantly greater reductions could be achieved if rates could be simplified, nor did it provide any insight into how best to achieve such simplification while reflecting sufficiently the key underlying economics of electricity supply.

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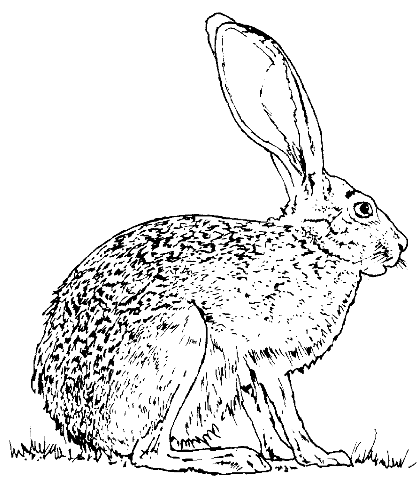
There are many ways to make tariffs simpler than those that currently exist in California and to help customers better understand and respond to price signals. Just simplifying bill presentment by creating a simple summary sheet at the top of the bill and placing the large amount of extraneous information contained in current bills (e.g., all the unbundled bill amounts) into a backup document would be a useful start. Of course, one could seek to simplify tariffs themselves. For example, a simpler dynamic rate is what some refer to as a ''pure CPP'' rate that is a rate that preserves the dynamic nature of critical peak pricing without the burden and confusion of facing a time-varying rate every weekday.

A pure CPP rate that has a high price on a limited number of ''emergency'' days, and a single low price on all other days with no increasing block structure, is a rate that would be pretty simple for customers to understand. On the other hand, it is a rate that focuses only on demand response and not on energy efficiency. Alternatively, one could use a more complex, cost-reflective tariff that incorporates time variation and increasing block pricing, and rely on technology to automate response to price changes or to translate the complex tariff into more understandable information through, for example, in-house displays that report cumulative and incremental bill amounts.

None of the above examples, however, address the most fundamental challenge of electricity pricing, namely, the fact that, no matter how simple the tariff, no customer knows what a kilowatt-hour is or how much it costs them to do a load of laundry or dishes or to run their refrigerator for a day. That is, no customer knows whether the simplest tariff, say 10¢/kWh, means that it costs 5¢, 25¢, or 50¢ to wash a load of dishes, or that a 5-degree change in a thermostat translates into a $1 savings on a typical summer day or a $2 savings on a really hot summer day. Consequently, there is a need to explore the extent to which service level pricing, that is, pricing based on the end-use services consumed, is feasible. Would an ''outside-the-box'' pricing strategy such as this improve consumer decision-making and could one be designed to accurately reflect the underlying economics of electricity supply? An example might be 10¢ for a load of wash done after 8 p.m. at night, but 30¢ for the same load done between noon and 8 p.m. during summer weekdays. While there are many practical challenges to implementing such an approach, the potential benefits could be huge from what might be the only sure way to significantly improve customer decision-making.

C. Equity

Equity in ratemaking can mean different things to different people. For some, it means preserving cross-subsidies and making sure that no one is made worse off relative to their existing situation. Of course, for this to be good for society, one has to assume that the existing situation was good to begin with. If the existing situation consists of significant cross-subsidies, it means that some individuals will be made worse off when those cross-subsidies are eliminated. Thus, the most conservative definition of optimality due to the Nineteenth and Twentieth Century Italian engineer, Vilfredo Pareto, rears its head and crimps forward progress. A Pareto improvement is one in which at least one person is made better off by a change in policy while no one is made worse



off. Adherence to only Pareto optimal changes makes it impossible to move to a better allocation of resources through more efficient pricing, even if people agree that is ultimately the correct outcome.

An alternative definition of equity means having lower rates for low-income consumers, as is the case with the California Alternative Rates for Energy (CARE)[11] program that provides a discount of 20 percent for low-income users. While rate options such as these are common throughout the industry, most economists would argue that they distort price signals and lead to excess electricity consumption.

A third definition of equity is accurate cost allocation—that is, setting prices so that they vary across customer classes or segments in accordance with variation in the cost of supply to those classes or segments. An example is having higher average prices for households with central air conditioning, or time-varying prices that incorporate the higher cost of supply associated with air conditioning loads during peak periods. Equity in this context focuses on eliminating cross-subsidies that are inherent in average cost pricing.

According to the second definition, lifeline rates (based on the theory that low-income consumers are low users) and explicit discounts such as the CARE tariff are worthy of pursuit. Lifeline rates (sometimes called baseline rates) are designed to meet the critical or lifeline needs of all consumers by supplying power at subsidized rates for the first several hundred kWh of usage. They serve a laudable social goal but detract from the overriding goal of economic efficiency. Commissions should reassess the logic of such rates and quantify the loss in economic efficiency they create. As a first step, they should quantify the extent of subsidy inherent in such rates. Suppose the full cost is 10¢/kWh and customers pay 7¢/kWh on the first 300 kWh of usage that is designated lifeline usage. That would suggest a subsidy of 3¢/kWh on 300 kWh, or $9. In the second step, the $9 subsidy would be converted into an income

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subsidy and the price on the first 300 kWh would be raised to its full cost of 10¢/kWh. To the extent that there is any price elasticity of demand, customers will lower their power usage when they see a price rise of some 40 percent on their first 300 kWh, even though they would be in receipt of an income subsidy that would allow them to consume the previous level.[12] In addition, removal of the price subsidies would improve the financial position of the electric utility. The financial burden of subsidizing customers would be shifted back to the state (and federal) government, on whose shoulders it should ultimately rest.

This social goal could be achieved without compromising the goal of basing prices on costs to achieve economic efficiency in the allocation of scarce resources by expanding the federal government's Low Income Home Energy Assistance program (LIHEAP). Begun in 1981, LIHEAP is a federally funded program to help low- and fixed-income Americans shoulder their home heating and cooling costs. It also provides funds for low-cost weatherization and energy-related home repairs. The Bush administration's 2006 budget proposal would have provided LIHEAP funding of only $2 billion,[13] forcing utilities to raise the subsidies they provide low-income customers.[14] This would not be an efficient outcome, for the reasons discussed earlier. Prior to the passage of the Energy Policy Act of 2005, the National Association of Regulatory Utility Commissioners called on the federal government to raise LIHEAP funding to $3.2 billion. The Act as passed raised it to $5.2 billion but as of this writing it was not certain that Congress would fund the entire amount.

Commissions need to test hypotheses about the distribu-

tional impacts of various rate options on different customer segments rather than basing them on supposition and conjecture. For example, do low-use customers have flatter load shapes than high-use customers? If so, they are likely to be made better off with TOU pricing and not worse off, as is often contended by some consumer groups. Many myths and preconceptions have grown around equity issues. The only way to slay the myths is to subject the implicit hypotheses concerning which tariff will make which customer group worse off to rigorous empirical quantification and analysis.

Fortunately, this can be done since new databases that quantify the response of customers to alternative rate designs now exist. A good example is the individual customer data that has been generated by the aforementioned SPP. To date, published analysis of the SPP data has focused on behavior of the average customer.[15] However, the database is a very fertile source of empirical information on customer response to rates that can be harnessed to test—and resolve—some of these distributional impacts that continue to be debated *ad nauseum*. It differs from the myriad datasets that are generated as part of ongoing load research activities such as cost-of-service studies, load forecasting, and direct access compliance.[16] Those datasets include information on hourly (and half-hourly) load shapes on a representative sample of customers but usually do not include information on customer characteristics (such as size and type of dwelling, saturation of end uses, and sociodemographic factors) nor do they include information on customer price responsiveness, both of which are richly represented in the SPP dataset.

D. Revenue recovery and stability

Revenue recovery and stability are key objectives of electricity ratemaking. There are significant challenges in maintaining revenue targets when moving from traditional tariffs to time-varying rates and these challenges vary depending on how the transition

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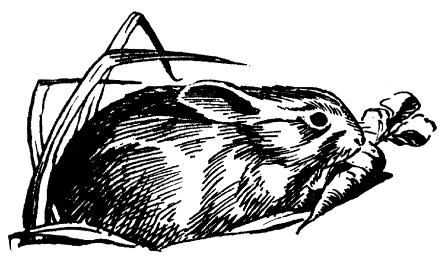
is implemented. For example, with purely voluntary, opt-in transition mechanisms, there are significant concerns about revenue reductions due to free riders. Mandatory and, to a lesser extent, voluntary opt-out time-varying prices have less risk of free-ridership. However, placing all customers on dynamic rates such as CPP can produce revenue instability, since a significant amount of annual revenue is collected on a small number of CPP days, not all of which may be called in any particular year.

The SPP database is also an excellent source to investigate the revenue impacts of various rate options. It can be used, for example, to identify the number and percent of free riders associated with various rate options, and the lost revenue associated with them. It could also be used to determine the amount of lost revenue resulting from calling fewer than the allowed number of CPP days in a year. Such information can be invaluable for identifying rate options that minimize lost revenue and maximize price incentives for energy efficiency and demand response.

E. Implementation feasibility and costs

Until recently, high metering costs have been a significant barrier to implementation of more economically efficient pricing that features time-based pricing. As seen in California's AMI proceeding, the incremental cost of implementing a wide variety of pricing options may be much lower in the future (after implementation of AMI) than it has been in the past. However, enabling technology, such as in home bill calculators and displays and automated response technology, are still costly and can be barriers to implementation of



some rate options that are too difficult to understand or respond to in the absence of such technology. Exploring the feasibility of and implementation costs and barriers associated with service-level pricing schemes, for example, would also be very important in determining whether or not such a paradigm shift in pricing strategy might be feasible in the medium to long run.

V. Rate Design Options

Examples of pricing options that we believe are worthy of consideration and evaluation by commissions and utilities in their next round of rate cases include:

- Modified non-time-varying default rates that reflect the insurance premium associated with providing rate stability in volatile markets (e.g., a constant price/kWh regardless of usage level)
- A rate based on a fixed bill (a constant bill over some period of time, regardless of usage) with a volatility avoidance premium
- Increasing block rates with a volatility avoidance premium
- Traditional TOU rates with a volatility avoidance premium
- Critical peak pricing, which features a traditional TOU rate on most days and a much higher peak period price on certain critical days
- Pure-CPP rate (e.g., a time-varying price on CPP days but not on other days)
- Real-time-pricing rate (one-part and two-part)
- Service-level pricing (based on end-use services) with no time-varying components and incorporating volatility avoidance premiums
- Service-level pricing with time-varying components

So there is a cornucopia of rate designs to consider and evaluate, using the Bonbright criteria discussed earlier. Since there are conflicts in the criteria, there is no way of avoiding tradeoffs. But before such tradeoffs can be made, it will be necessary to quantify the impact of the rates on each criterion, using a database such as the SPP database discussed earlier. The objective of such a rate design evaluation should not be to identify the

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optimal rate (e.g., one that performs best according to some weighted average of the multiple criteria), as doing so would require placing relative weights on each criterion. Furthermore, what is optimal in one setting may be suboptimal in another, making the idea of optimality a chimera. Rather, the objective should be to demonstrate how a simple framework based on multiple evaluation criteria could be used to compare pricing and incentive options. More importantly, this process can be used to identify important issues, implementation barriers, and information gaps that could be addressed through future pilot programs and rate research.

Pricing options should be evaluated singly and in combination. For example, increasing block rates provide an incentive for efficient electricity use. Critical peak pricing rates provide an incentive for reducing peak load that is especially strong on critical peak days. They should both be implemented if they reflect marginal costs, in which case a combined rate may need to be offered. Thus, a CPP rate would be designed that follows an inverted block structure, perhaps by overlaying surcharges during the peak period and credits during the off-peak period. Such a rate was indeed tried and tested in the SPP and surveys indicated that most customers had no difficulty understanding it.

Another option would be to offer end-use pricing options layered on top of a time-varying rate structure. Thus, customers would be charged separately for refrigeration and pool pumps, and would pay more (on a unit basis) for the second refrigerator than for the first one. The benefit of such a rate design is that it would make the decision to buy electricity very similar to that of buying any other good or service.

However, this approach would require a number of technological advancements in order to be implemented. It will require research to assess its feasibility.

Such pricing options should be compared with cash rebate programs such as the Energy 20/20 program and the ever-popular cash incentive programs for customer participation in direct load control of air conditioners. As argued earlier, cash rebates are blunt instruments that tend to overpay low users and underpay high users relative to benefits achieved. They bring along with them a host of free riders that are paid for doing nothing. They create new cross-subsidies that create their own constituencies over time and are hard to dislodge. On the other hand, they are easy to understand. It would be important for utilities and commissions to determine the costs and benefits of such ''pseudo-rate'' programs and compare them with the real ones listed earlier.

Furthermore, how well each pricing/incentive option meets the relevant criteria will vary across customer segments. For example, complex tariffs are more easily understood by large, sophisticated energy consumers than they are by residential consumers. Feasibility and cost barriers to implementation are also greater for residential customers than for large commercial customers. Thus, option evaluation must be done separately for mass-market versus large business customers. Because of the free-ridership and other issues discussed above, how various pricing options rate may also vary depending on whether they are default or opt-in rate options.

VI. Conclusions

The next wave of rate cases that is moving through the industry will shape its future evolution for years to come. The time has come for utilities and commissions, working with the various publics that are involved in rate cases, to resolve the paradox posed by an Englishman, D. J. Bolton, more than half a century ago: ''There is general agreement that appropriate tariffs are essential to any

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rapid development of electricity supply, and there is complete disagreement as to what constitutes an appropriate tariff.''[17]

A key part of developing an appropriate tariff is getting the right rate design. This article has presented several ideas that should be on the regulatory agenda in the future. We hope they will be taken up for analysis, discussion, and debate in the months and years to come.■

Endnotes:

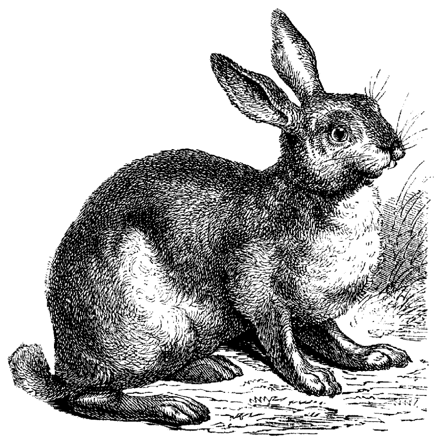
1. For a discussion of rate cases in the gas industry, see S. Lawrence Paulson, *The Yin and Yang of Rate Design*, Amer. Gas, Oct. 2005.

2. *Ratemaking in a New World: Another Perspective*, Electric Perspectives, May/June 2004, available at http://www.eei.org/magazine/editorial_content/nonav_stories/2004-05-01-AP.pdf.

3. Executive Order D-30-01, Mar. 13, 2001, modified by D-33-01, Apr. 26, 2001. Perhaps the rates fracas in San Diego had chastened the governor. In the summer of 2000, as wholesale prices rose to unprecedented heights in California, San Diego Gas & Electric passed through these prices to retail customers, provoking a revolt from customers who saw their bills doubling and tripling. In retrospect, the impact on customer bills could have been averted by using a two-part rate design of the kind discussed in the next section or by offering customers a variety of hedged pricing products. See Ahmad Faruqui and Kelly Eakin, *Summer in San Diego*, Pub. Util. Fortnightly, Sept. 15, 2000.

4. http://www.energy.ca.gov/releases/2002_releases/2002-05-23_governor_20-20.html and Greg Wikler, Patrice Ignelzi and Omar Siddiqui, *CALMAC Summer Study: A Retrospective of California Energy Efficiency Programs in 2001*, ACEEE National Conference on Energy Efficiency as a Resource, 2004.

5. Kevin Coughlan, *A 20/20 Ex Post Look at California's 20/20 Rebate Program*, presented at 15th Western Conference, Center for Research in Regulated Industries, Rutgers Univ., June 2002. Coughlan cites a study by Andrew Bell of PG&E that shows that about 20 percent of all customers use 20 percent less electricity from year to year and another 20 percent use 20 percent more.



6. Antonio Alvarez, *Avoided Generation Cost Inputs*, Pacific Electric & Gas Company's Advanced Metering Infrastructure filing with the CPUC, June 16, 2005.

7. David M. Gamson, *Economic Analysis and Decision Making at the California Public Utilities Commission*, 18th Annual Western Conference, Center for Research in Regulated Industries, Rutgers Univ., June 22, 2005.

8. We are grateful to Luiz Maurer of the World Bank for providing us information about Brazil's innovative program.

9. James C. Bonbright, Albert L. Danielson and David R. Kamerschen, with assistance of John B. Legler, Principles of Public Utility Rates, 2nd ed. (Arlington, VA: Public Utilities Reports, Inc., Mar. 1988).

10. Ahmad Faruqui and Stephen S. George, *California Experiment: Dynamic Pricing for Mass Markets*, Pub. Util. Fortnightly, July 1, 2003.

11. Low-income customers have an income of less than $27,700 for one or two household members. The threshold income rises to $45,900 for households with five members. Enrolled customers are also protected from the emergency rate increases that took place in 2001.

12. They will use some portion of the income subsidy to buy other goods and services that are higher valued than electricity. If the price elasticity of demand is −0.2, a price rise of 40 percent will result in a drop in consumption of approximately 8 percent. On a consumption of 300 kWh, this would represent a drop of 24 kWh, which when added over a million customers becomes 24 million kWh per month or 288 million kWh per year.

13. The funding level was $1.9 billion in 1982. It had dropped to $1.3 billion in 1993. By 2004, it had risen back to its initial level of $1.9 billion in nominal dollars but was only $1.0 billion in constant dollars. In the mean time, the number of low-income families had increased by 50 percent. About 5 million families, or less than one-fifth of the eligible total, take advantage of the program. See *Keep the Heat on LIHEAP: Another Perspective*, Elec. Perspectives, Mar./Apr. 2005, and http://www.neada.org/appropriations/LIHEAP_Appropriations_History.pdf.

14. Utilities distributed $700 million to low-income households in 2001, presumably through rate discounts.

15. Ahmad Faruqui and Stephen George, *Quantifying Customer Response to Dynamic Pricing*, Elec. J., May 2005.

16. See for examples the class load profiles collected by Pacific Gas & Electric Company at http://www.pge.com/nots/rates/006f1c4_class_load_prof.shtml and http://mads.pge.com/profiles/.

17. Preface to first edition of Bolton, published in 1938, cited in D.J. Bolton, Electrical Engineering Economics, *Vols. 1 & 2* (London: Chapman & Hall Ltd., 1951).